

# Tropospheric HDO/H<sub>2</sub>O distribution over the Southeast Atlantic Ocean from satellite, aircraft and model



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## INTRODUCTION

The value of water isotopologues (H<sub>2</sub>O, HDO) to the water cycle comes from the quantified isotopic fractionation in nature. Lighter isotopologues of water (H<sub>2</sub>O) preferentially evaporate. Heavier isotopologues (HDO) preferentially condense. Different moisture sources have different isotopic compositions.

Recent findings include:

- Quantifying rainfall evaporation in tropical monsoons (Worden et al., Nature 2007)
- Partitioning transpiration and river run-off (Good et al., Science 2015)
- Amazon transpiration initiates rainy season (Wright et al., PNAS 2017)

## NASA Earth Ventures Suborbital (EVS-2) ObseRvations of Aerosols above CLouds and their interActioNS (ORACLES)

- A multi-year (2016-2018) investigation to study key processes that determine the climate impacts of African biomass burning aerosols.
- Water Isotopologue measurements from the OSU Water Isotope Spectrometer for Precipitation and Entrainment Research (WISPER) on the ORACLES NASA P-3B Orion aircraft.

## Isotope Community Atmosphere Model (iCAM)

- Water isotope version of CAM developed by David Noone group (Nusbaumer et al., 2017).
- 30 levels (3.6 hPa to surface), including ~20 levels in the troposphere.
- Objective is to use the ORACLES observations to benchmark the model, and to compare variability between AIRS, ORACLES and model.

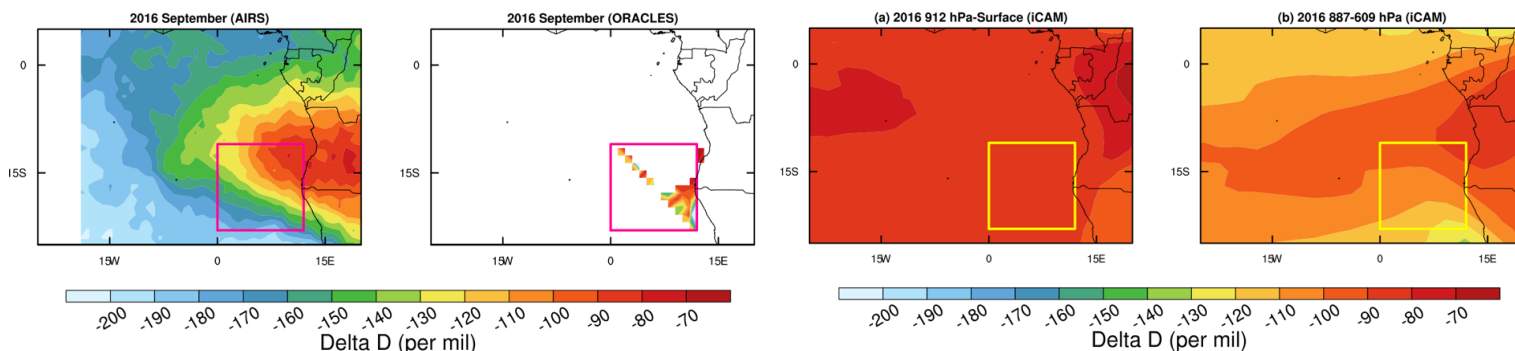


Fig. 1: Maps of Delta-D over Southeast Atlantic Ocean and Southwest Africa in September 2016. Left to right: AIRS (825-562 hPa averaged), ORACLES (825-562 hPa), iCAM BL (912 hPa-surface) and iCAM free trop. (887-609 hPa).

## HDO and H<sub>2</sub>O Optimal Estimation Retrieval

We present retrievals of the deuterium content of water vapor from the Aqua Atmospheric InfraRed Sounder (AIRS). Single footprint AIRS radiances are processed with an optimal estimation algorithm that provides a vertical profile of the HDO/H<sub>2</sub>O ratio, characterized uncertainties, and instrument operators also known as the averaging kernel matrix.

- Optimal Estimation approach to retrieve Level 2 data products from AIRS single footprint IR geolocated and calibrated radiance data (Worden et al., 2019). AIRS HDO/H<sub>2</sub>O DOFS is approximately 1.5 in the subtropics.
- AIRS single footprint pixels with nadir horizontal resolution of 13.5 km.
- The Retrieval Framework is an optimal estimation retrieval algorithm (TES heritage) in which HDO is retrieved from AIRS.
- AIRS radiances are utilized from ~650 to 1340 cm<sup>-1</sup> (excluding the ozone band).
- AIRS and TES show a small bias for the HDO/H<sub>2</sub>O ratio of 0.32 ± 2.3% (Worden et al., 2019).

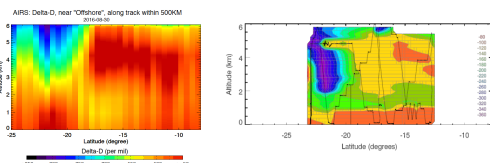


Fig. 3: Cross-section of Delta-D from AIRS (left) and ORACLES (right).

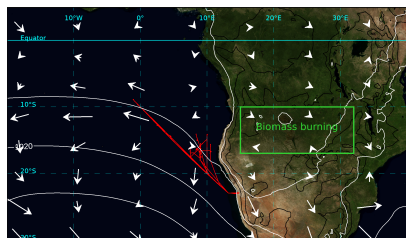


Fig. 2: NASA P-3 aircraft flight paths (red) during ORACLES 2016, with sea level pressure (white isobars) and 700 hPa winds (white barbs) from MERRA2.

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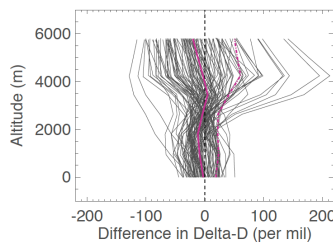


Fig. 4: Comparison of AIRS minus aircraft in-situ Delta-D with the averaging kernel applied, with mean bias (solid red line) and RMS (dash-dot red line).

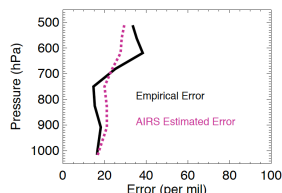


Fig. 5: AIRS Estimated Error (dotted red line) and empirical error (solid black line) from satellite-aircraft comparisons.

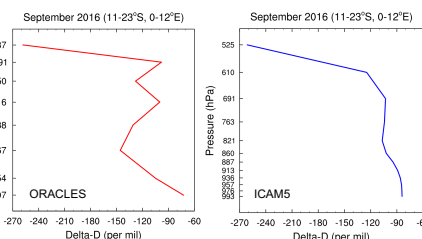


Fig. 6: Monthly mean vertical profiles of Delta-D from ORACLES (left) and iCAM (right) for September 2016 over Southeast Atlantic Ocean.

## SUMMARY

- AIRS HDO/H<sub>2</sub>O retrievals are very well characterized ~1.5 DOFS.
- AIRS bias relative to the aircraft is -8.0‰ in the lower troposphere and -4.6‰ in the middle troposphere.
- AIRS RMS (in Delta-D notation) is 25 to 30‰, consistent with aircraft RMS.
- The small bias and consistent RMS suggests that the AIRS HDO/H<sub>2</sub>O retrieval provides well characterized measurements. This level of uncertainty is good enough to address science questions.
- Initial comparisons of iCAM model with AIRS show similar vertical shape, but with a ~60‰ offset.
- Next step is to quantify isotopic variability in the model and determine source of offset.

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